Experiment II

Ohm's Law and Resistor Circuits

Introduction

In this experiment you will test Ohm's "law" for a carbon resistor. Then, using this "law", you will determine the equivalent resistance of 2 or more resistors connected in series and parallel.

Theory

Ohm's law states that for an ohmic conductor, the current I through the conductor is directly proportional to the voltage V applied across the conductor. That is,

$$I \propto V \text{ or } I = CV \quad \text{where C is a constant.} \tag{2.1}$$

The constant of proportionality C is written as 1/R so that

$$I = V/R \quad \text{and R is called the resistance.} \tag{2.2}$$

Thus, the higher the resistance the lower the current for a given applied voltage. R has units of volts/amps or ohms (Ù).

Ohm's law, V = IR is only an approximation for the electrical behavior of certain materials under certain conditions. The resistance of many conductors such as metals increases with increasing temperature. When a current I flows through a resistance R, heat is generated at the rate, I^2R (Joule heating). Thus, if enough current flows through a resistor to cause it to heat up appreciably, it will behave in a non-ohmic way and one cannot speak of the resistor as having a certain fixed resistance for all currents.

Procedure

Part I. A study of Ohm's Law

Your instructor will discuss with you the use of ammeters and voltmeters. The main points to remember are that a voltmeter has a high resistance and is attached *across* the ends of a circuit element to measure the voltage between the ends of the element. An ammeter has a low resistance and is *never placed across* the ends of circuit element. It is always wired into a circuit so that it *acts as a connecting wire* to the circuit element whose current is to be measured.

Construct the circuit below to study Ohm's law for the resistor.

The element on the left is a power supply set at 5 VDC. The 340 Ù rheostat is connected as a voltage divider. By moving the rheostat wiper, the voltage across R can be varied from 0 to 5 V. Use one of the three carbon resistors on the board given you as R.

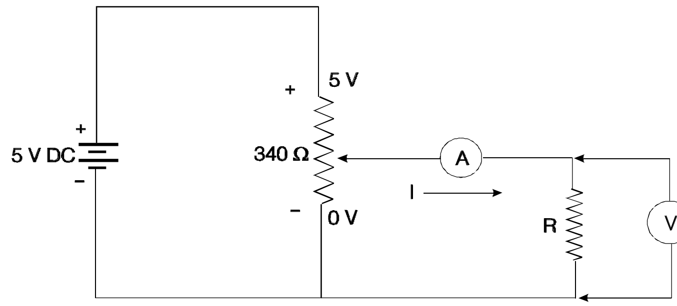

Figure 2.1 - Ohm's law.

Note that the voltmeter V is connected across the ends of R. V and R are said to be connected in parallel. On the other hand, the ammeter A connects the rheostat to the resistor and is said to be in series with the resistor.

Measure the current I through R for at least 5 voltages across R between 1 and 5 volts. Note that if you change to a new ammeter scale after you have set the voltage, you will need to reread or reset the voltage because the ammeter resistance changes with a change in scale.

Make a linear plot of V versus I. You may do this on the computer using the program "Quattro Pro". Assume that the meters are accurate to a few percent in estimating your error in V. (We will ignore the fact that the meter readings for small deflections tend to be less accurate than those for large deflections.) Do your data support a straight line fit? That is, does Ohm's law V = IR appear to be obeyed? What value do you obtain for R?

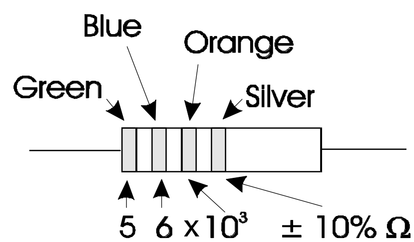

Figure 2.2 - A 56 kÙ resistor.

Compare the value of R obtained from your analysis with the value given by the color codes on the resistor. (See Figure 2.2.) Then compare your value for R with the value obtained by a direct measurement of R using an ohmmeter furnished by your instructor. Note on determining the value of a resistor using its color bands; Black=0, Brown=1, Red=2, Orange=3, Yellow=4, Green=5, Blue=6, Violet=7, Gray=8, and White=9; Silver=10% and Gold=5%.

Part II

A. The Equivalent Resistance of two or more Resistors connected in Series.

Wire the series circuit as shown in Figure 2.3 using two of the carbon

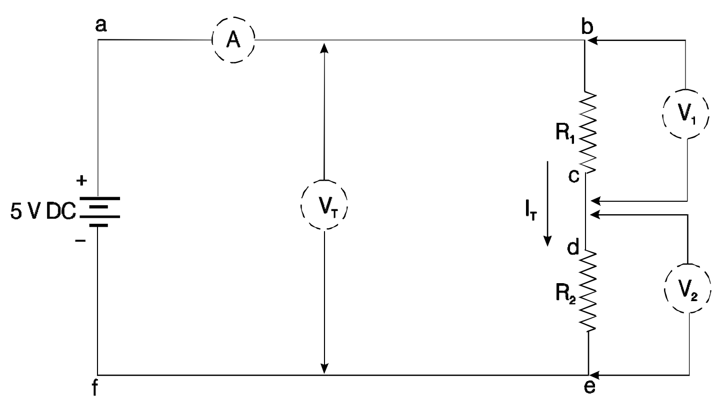

Figure 2.3 - Resistors in series.

resistors furnished. Measure the current *along* ab, cd and ef. Next measure the voltage *across* af (V_T), bc (V_1) and de (V_2).

Note that the dashed circles indicate the different places you will need to put the ammeter and voltmeter to make the required measurements. It is generally best to wire up your circuits first *without* any meters and then to insert and *remove them* as needed.

Attach the voltmeter to measure V. Set the power supply so that $V_T = 5$ V. Then measure the voltages V_1 and V_2, across each of the resistors. Does $V_T = V_1 + V_2$ within experimental error?

Now measure the current entering R_1 on the + side, the current flowing between R_1 and R_2 and the current leaving R_2. How do these currents compare? What can you say about the current anywhere in a series circuit?

Since you have measured V_T and I_T, you can determine the equivalent resistance, R_{eq} of your circuit from Ohm's law, $V_T = I_T R_{eq}$?

Similarly from I_T, V_1 and V_2 you can determine R_1 and R_2. Compare the sum $R_1 + R_2$ to R_{eq} as determined above. Does it appear that R_1 and R_2 in series have an equivalent resistance $R_{eq} = R_1 + R_2$?

Note that once you have found R_{eq} for two resistors in series, the addition of a third series resistor R_3 gives a total equivalent resistance of $R_{eq}(1,2) + R_3 = (R_1 + R_2) + R_3 = R_1 + R_2 + R_3$. *Hence the equivalent resistance of any number of resistors in series is the sum of the individual resistances.*

B. The Equivalent Resistance of two or more Resistors connected in Parallel.

Wire the two resistors that you used above into parallel circuit as shown in Figure 2.4.

Note that in drawing a circuit it is always assumed that the connecting wires have a negligible resistance compared to any resistors in the circuit. This being the case here, both R_1 and R_2 have the same voltage V_T, across them. By definition, two in parallel have the same voltage across them. Insert the voltmeter to measure this voltage V_T. Adjust the power supply so that $V_T = 5$ V. Now measure the total current I_T and then the individual currents I_1 and I_2 through, R_1 and R_2. Does $I_T = I_1 + I_2$ within experimental error?

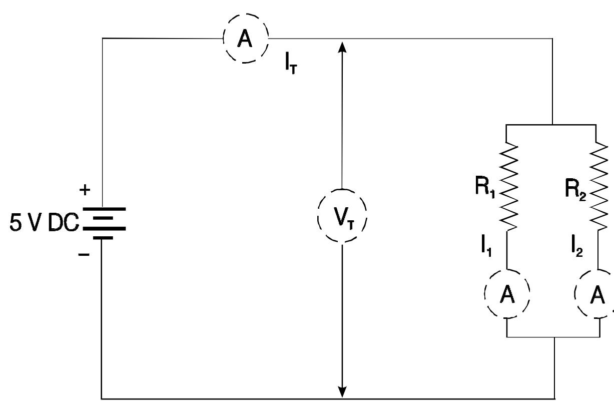

Figure 2.4 - Resistors in parallel

The equivalent resistance of R_1 and R_2 is again defined by $V_T = I_T R_{eq}$.

What value do you find for R_{eq}? What values do you find for R_1 and R_2? Compare your value for $1/R_{eq}$ with the sum $1/R_1 + 1/R_2$. Are your measurements consistent with the statement that for two resistors in parallel,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} ? \tag{2.3}$$

Note that if a third resistor R_3 were to be added in parallel to R_{eq} of R_1 and R_2 the new equivalent resistance would be given by

$$\frac{1}{R_{eq}} = \frac{1}{R_{eq}(1,2)} + \frac{1}{R_2} \tag{2.4}$$

But this is just

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \tag{2.5}$$

so that the extension to any number of resistors in parallel is now evident.

Conclusions

Summarize what you have learned about the voltages, currents, and equivalent resistances in series and parallel resistor circuits.

Part III.

If time permits connect a small light bulb in the circuit shown below.

Vary the power supply from 1 to 5 V and record the current I flowing through the bulb. Check to see if the light bulb obeys Ohm's law.

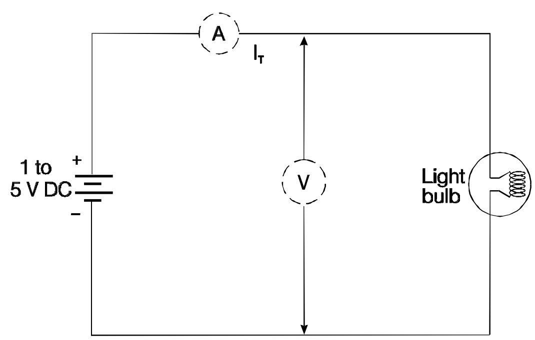

Figure 2.5 - Temperature dependent resistance.